Integrated Greywater Reuse System in Residential Buildings

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Abstract – *In today's world, water shortage is one of the major issues which necessitate greywater treatment options generated from domestic sources and need for conceptualizing a proper treatment technique to reduce cost. For our existence, water is essential source. Due to gigantic increase of population and rapid rising of industrialization the need for pure water is rising. Greywater have the potentiality to reduce the impact of scarcity circumstances. The benefit of regimented greywater management system is that it offers a tool for coping with water insufficiency. The presence of microorganisms, chemical contaminants and physical contaminants makes the pure water distinct from the greywater. To tackle the challenges of water scarcity, an attempt has to be made in this project to utilize treated greywater obtained by filtering techniques through polypropylene filter followed by gravity governed filtration which is constructed by the changes in layer arrangements and by the assimilation of new material . This study deals with the design of a filtering system to propose an Integrated Greywater Reuse System (IGRS) for household application. The treated water is also subjected to laboratory assessment before and after the treatment.*

***Key Words*: Water shortage, Grey water, Pure water, Filtration, Assimilation, Household application**

1. INTRODUCTION

The demand of clean water is increasing by the city expansion and due to the industrial advancements. With increase in population density, there will be an increase in tension of waste disposal methods and systems[1]. It is vitally important to treat wastewater in order to create a sustainable environment and protect from pollution. Enormous studies are conducting in different parts of the world using greywater with different technologies and advancements. Greywater is the wastewater usually generated from the kitchen sink, shower, laundry or washing machine etc., which is conveying through as a waste[1]. By treating the grey water properly, it can be reused for drinking as well as for domestic applications. The formal connection between sewerage treatment and the filtration always influence the concept of water treatment. The generation of high quality effluent makes the filtration method unique from other substantial mechanisms. The incorporation of newly additive material in the filtration practices enhances the efficiency as well as the insistence. The conventional practices works within the certain limits according to the ability of the used materials. The paper gives a detailed description about the grey water reuse system which is affordable and based on the relevance of the execution of such systems.

2. LITERATURE REVIEW

- GRAVITY GOVERNED FILTRATION AND THE GROUND WATER RECHARGING

The work done by **Harish et al. (2019)** was reviewed[1]. The chances of ground water recharging with the treated water are highlighted in his paper. The centre of attention of the treatment mechanism is the gravity-governed filtration which comprises sand, gravel, and activated carbon. Water which is the mixture of equivalent amount from the kitchen sink, washing machine and shower from three distinct regions of Kuwait was taken for the study. The study concluded that the removal efficiency of the designed column for first 1000 ml and the second 600 ml after washing was recorded as 34%and 26% respectively[1]. The physical, chemical and microbiological characters are ascertained in order to check the feasibility of the treatment system. The comparison between the groundwater quality of Kuwait group and Dammam aquifers are also given significant importance.

- INTERIOR CUSTOMIZED GREYWATER SYSTEM

The work done by **Yi-Kai et al. (2016)** was reviewed [7]. He tried to propose an Interior Customized Greywater System (ICGS) which is based on the application for the family unit of four as target in Taiwan and also the pipeline configuration study was performed. This system can be commissioned and designed which is adjustable in the household space. System configuration and design based on real cases is performed for checking the feasibility aspects. The cost economic analysis with a life cycle of 20 years is examined with three scenarios for the utility purpose and for the customer's satisfaction [7]. The minimum payback period of 4 years is ensured with obtained results. The ICGS can provide inconspicuous output in the regions of high water cost and water scarcer areas.

- OVERVIEW OF PHYCOREMEDIATION PROCESS IN GREYWATER

The work done by **Mohamed et al. (2017**) was reviewed[3]. The detailed investigations of the phycoremediation using the Botryococcus sp. of the bathroom greywater in village houses of four families were evaluated. It mainly aims at the high effectiveness for the treatment system, which is performed at an ambient temperature of 21 days. With the minimum of 3 days, required for the phycoremediation process, there will be significant removal of nutrients and the metals from the corresponding greywater. The conducted test reveals the significant reduction of COD and BOD (Chemical oxygen demand and Biological oxygen demand). The applicability range of the phycoremediation system was enhanced, due to the recognizable removal percentage of potassium (3days) and calcium (21days)[3]. In spite of this, the effect of no energy requirement and the exhibition of non-toxic byproducts strengthen the implementation capability of the respective treatment system. The description in this paper promises the reduction in the discharge of contaminants from the greywater after the treatment[3]. The inspiration acquired from the importance of sustainable environment paved the way for the initiation of the respective treatment mechanism.

3. MATRIALS USED

With the knowledge acquired from the literature section, the materials required for the design of the filtering system is selected. There are many factors contributing for the selection of suitable materials for the identifiable output. The materials required for the designing process are illustrated below.

- **POLYPROPYLENE FILTER**

The high bacterial resistant property of the polypropylene fiber makes its wide applicability in markets than the cellulose. The mechanical process takes place in the polypropylene filter shows the high holding capacity along with high flow rate with the efficient removal of contaminants including the sand particles, dust particles and the fine corrosive impurities. In this design setup the polypropylene material is inserted as a cartridge unit. The ideal choice would be a 20 micron filter followed by a 5 or 1 micron filter. However, it is mainly depends on the quality of water supplied. The clear marking of the size is provided in the filter cartridge. The size and the technical specifications are provided on the table.

Table 1 Technical Specification of the Filter

sizes	10 x 2.5 inch
Micron rating	5
diameter	2.5”
weight	80 gram
Product life	4-6 months (expected)

Fig. 1 Polypropylene Filter Cartridge[9]

- **COARSE AND FINE GRAVEL LAYER**

These layers have the key role in the filtration process and the expected outcome will be only possible by the significance performance by this predominant layers. It is basically a vertical filter, framing layers of fine and coarse gravel. The holding capacities of gravel to resist the passage of the suspended solid particles in the grey water reduce the contamination of the corresponding water and accelerate the following mechanisms. The water percolates down to the next layers under gravitational pressure and the process takes place in the gravel layers, limiting the level of contamination in the greywater. A 30cm distribution layer of fine gravel, 8-20mm diameter and another 30cm layer of coarse gravel of grain size 20-30mm are provided for the design setup. The image of the fine and coarse gravel are shown below in Figure 2 and Figure 3.

Fig. 2 Fine Gravel[8]

Fig. 3 Coarse Gravel [8]

- **ACTIVATED CHARCOAL**

The fine black powder obtained from the combustion of bone char, coconut shells, peat, petroleum coke, coal, olive pits is referred as the charcoal. The normal charcoal is extensively reliable in markets in the activated form by transferring through certain processes at high temperatures. The significant reduction in the size of pores and in the surface area makes its value and the demand much better. The hydrophilic nature of the activated carbon makes the adsorption process effectively and thereby the filtration[1]. The compounds present in the greywater are subjected to the adsorption mechanism by surface interactions between the compounds present in the water and the activated carbon. The negatively charged pores of the charcoal get attracted by the oppositely charged impurities present in the water. The image of the activated charcoal is depicted below in Figure4.

Fig. 4 Activated Charcoal[4]

- **FINE AND COARSE SAND LAYER**

The predominant contribution of framed sand layers accelerates the performance of the filtration unit. The grading of the sand selected for the layer arrangement should be correct in order to exhibit the excellent output from the filtration system. The resistive nature and the holding capacity of the pores in the sand layers make them useful for the water filtration in every aspect. The filter layer of coarse sand, minimum 60cm in depth and the fine sand is required for the layer distribution. The size of fine sand should be 0-4 mm, while in the case of coarse 4-8mm. The images of the fine sand and coarse sand are shown below in Figure 5 and Figure 6.

Fig. 5 Fine sand[2]

Fig. 6 Coarse sand[2]

- **GRAPHENE**

Research in the field of graphene is continuously under process in different parts of the world. The outstanding ability of graphene as adsorbent to erase the organic pollutants and the impurities in water makes them potential in the water purification process. We tried to consider this unique property of graphene and thereby making the filtration system as an effective one[10]. The treatment system we used is quite conventional, but the introduction of the graphene and the changes given on the layer arrangements in filtration tank makes it unique from others[10]. The Graphene is the allotropic form of carbon which exhibits the hexagonal structural pattern with four bonds, one σ-bond with each of its three neighbors and one π-bond that is oriented out of plane as shown in figure 7. The graphene in layers reduces the contaminant concentration and assist to extract them clear[10].

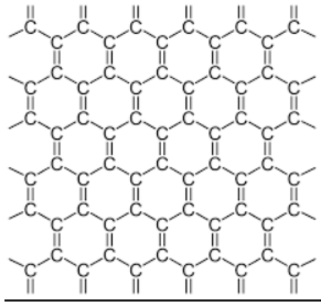

Fig. 7 structural form of Graphene[6]

The higher cost of graphene is one of the major crises that we faced in the construction of the system .But the removal efficiency of the material with the trace amount of it makes more applicable. For the miniature setup of this system, we adopt 10gm of the graphene powder (industrial grade product). The image of the material is shown in Figure 8 depicted below.

Fig. 8 graphene powder (industrial grade)

4. METHODOLOGY

The grey water samples were collected from three different houses located in Kottayam district of Kerala, India. The physical and chemical properties of the collected grey water are then analyzed in a laboratory. These parameters will determine the quality of the collected greywater. The greywater we collected is shown in figure 9. After the detailed examination in the laboratory, the greywater is subjected to pass through the designed filter. The filtration unit starts from the polypropylene filter. Then it is passed through the gravity governed filtration tank. The layer arrangements in the filtration tank are as follows in the table 2.

Table 2 Layer arrangements in the filtration tank

Tank 1	Tank 2
Fine gravel	Fine gravel
Coarse gravel	Coarse gravel
Fine sand	Fine sand
Coarse sand	Coarse sand
Activated charcoal	Graphene powder
Fine sand	Fine sand
Coarse gravel(drainage layer)	Coarse gravel(drainage layer)

Fig.9 Greywater collected

The water collected from the two tanks is further subjected to the disinfection process using the bleaching powder. The treated water then used for the domestic purposes such as car washing, gardening, bathroom flushing [1]. The experimental designs under working condition of the filtration system are depicted in the figure 10.

Fig.10 working model of filtration system

The water thus collected was also subjected to laboratory assessment to ascertain the physical and chemical properties. The tests are conducted for the water collected from the three houses which are under consideration. The schematic diagram of the basic filtration method is also depicted below in the Figure 11.

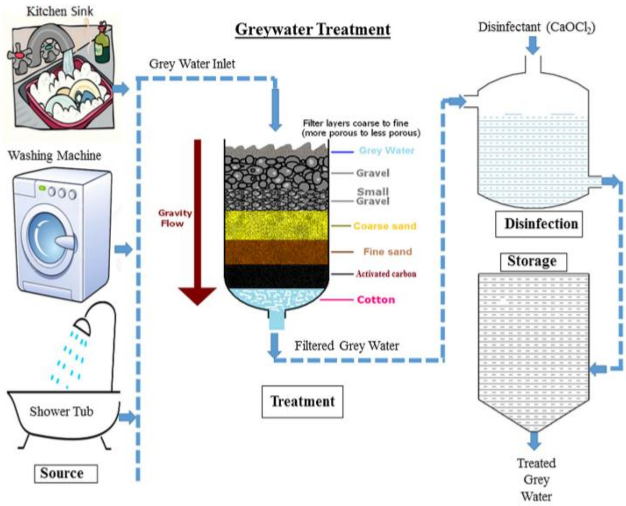

Fig. 11 Schematic diagram of the filtration method[1]

5. RESULTS AND DISCUSSIONS

5.1 Untreated water and Treated water

Untreated water

The presence of organic and inorganic contaminants in the water should be detected before the treatment. Here, some basic parameters are assessed to determine the quality and the amount necessary for the supply of filtering materials. The water collected from three houses has an average pH of 8.6. pH plays an important role to determine the acidic and basic nature of the water. The total solids in the water can be assessed in terms of Electrical conductivity, one of the major parameters. The average electrical conductivity and the total dissolved solid are obtained as 4819 µS/cm and 3083mg/L. Turbidity is the another factor to determine the water quality as well as the amount of suspended solids. Here the average turbidity is obtained as 266 NTU. The variations in the turbidity values are useful to determine the quality of filtration technique before it is subjected to domestic purposes. Turbidity measurements are also helpful to identify the effectiveness of the treatment method[5]. The physical, chemical and microbiological parameters of the untreated water from three houses are depicted in the table 3.

Table 3 untreated water characteristics

Parameters	units	1	2	3
pH	-	8.25	8.48	9.12
Electrical conductivity	µS/cm	4735	4810	4912
Total dissolved solids	mg/L	3030	3078	3143
Total suspended solids	mg/L	146	152	151
Turbidity	NTU	254	268	278
Chemical Oxygen Demand	mg/L	525	516	531
Sodium	mg/L	16.3	19.00	23.7
Potassium	mg/L	4.17	4..37	6.53
Calcium	mg/L	33.8	34.6	42
Magnesium	mg/L	5.74	5.29	6.15
Nitrogen	mg/L	9.68	8.12	9.47
Iron	mg/L	0.36	0.26	0.11
Total coliform	MPN/ 100ml	$9X10^7$	$11X10^7$	$25X10^7$
Escherichia coli	MPN/ 100ml	$.5X10^8$	$0.8X10^8$	$1X10^8$

Treated water

The water after the filtration is also analyzed in the laboratory in order to verify the changes in the contamination level. Significant changes in water characteristics especially the color and odor indicates the reduction in the biodegradable and non-biodegradable pollutants in the water[5]. The average pH of water significantly reduced from 8.6 to 7.2. Turbidity, one of the major factors reduced from 266 NTU to 23.5 NTU. The obtained result shows that the method exhibits excellent performance in the removal of organic and inorganic pollutants. The figure 12 shown below indicates the identifiable reduction in the amount of dust particles and color even in the first stage of filtration method.

Fig. 12 filter cartridge after filtration

The table 4 shown below reveals the experimental results of the treated water and the significant changes in the water quality which enhances the possibility of application in the household space.

Table 4 Treated water characteristics

Parameters	units	1	2	3
pH	-	6.9	7.3	7.4
Electrical conductivity	µS/cm	2312	2451	2512
Total dissolved solids	mg/L	1232	1330	1212
Total suspended solids	mg/L	12	13	10
Turbidity	NTU	23.6	29	18
Chemical oxygen demand	mg/L	83	77	72
Sodium	mg/L	152	113	149
Potassium	mg/L	9.2	8.1	7.3
Calcium	mg/L	125	134	112
Magnesium	mg/L	4.36	1.35	7.29
Nitrogen	mg/L	1.20	2.95	1.25
Iron	mg/L	0.205	0.354	0.226
Total coliform	MPN/ 100ml	<0.1	<0.1	<0.1
Escherichia coli	MPN/ 100ml	<0.1	<0.1	<0.1

The results given in the table 4 shows the performance efficiency of the filter system. The removal efficiency of the filtering media can also be assessed. The power of graphene in trace amount reduces the microbial growth as well as also the odor problems. The low to medium strength greywater can be easily recycled using this process. Disinfection using bleaching powder prior to this mechanism will reduce further contamination in the water[1]. The amount of bleaching powder applied, basically depends on the quality of water. Higher traces of bleaching powder will also cause severe health problems. So we have to carefully handle the situation of applying the amount of disinfectant. The efficiency analysis in terms of treatment performance, quality assurance can also be assessed.

6. CONCLUSIONS

The filtration methods, capability of the filtering media, treated and untreated water qualities are discussed here. The purpose of treated water should be based on the water quality. The following conclusions can be withdrawn from the conducted study;

- The treated water can only make useful for the non-potable purposes, such as car washing, bathroom flushing, gardening etc. The figure13 shown below depicts the usage of treated greywater.

Fig. 13 Application of Treated Water[1]

- The treated water inferred to be effective for drinking purpose after the UV treatment technology. The quality assurance of this recycled water is still under process.

- From the analysis of treated and untreated water, a significant change in pH from 8.6 to 7.2 clearly shows the quality changes in the water. Hence the system is stable in low to medium strength concentration of greywater. Processes taking place in the filtration tank can efficiently remove the suspended solids, sand particles and organic pollutants.

- The further presence of detergent concentration is the major threat that we faced after the treatment. Graphene have the ability to remove the hardness in water in trace amount. Studies are still under progress to tackle this challenge.

- This study inspires us and gave a new outlook to the treatment mechanisms with the changes introduced in the layered arrangements and by the introduction of one additive material in gravity-governed filtration tank.

- The motivation from the concept of Reduce, Reuse, Recycle helps to initiate and complete this study.

- From the knowledge obtained in the literature section, we have developed a new filtration system which can be adjustable in household space. The economic analysis can also be performed after the implementation of this system in the houses as an experimental setup.

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